STATUS REPORT

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I. INTRODUCTION

The principal objective of this grant, described in section 2.1 (a - d) in the original proposal is the analysis of spacecraft data for cosmic-ray anisotropies, and the continuation of our program of related theoretical research. We have made considerable theoretical progress (see sections 3, and the Current Bibliography at the end of this report). We have also begun analysis of the IMP-6 particle and field data tapes supplied to us by Drs. Frank McDonald and Donald Fairfield at GSFC. Spacecraft data analysis is a new effort for us, and, as might have been expected, we have found it both necessary and interesting to study aspects of this data which we did not anticipate. This had delayed the straight forward progress of the analysis. We have also found some technical anomalies which we expect to resolve soon in consultation with our collaborator Dr. Tycho von Rosenvinge at GSFS. We expect that we will have publishable results from the data analysis in the next few months.

2. ANALYSIS OF SPACECRAFT DATA

We have begun by studying the particles recorded by the NASA/GSFC Very Low Energy Detector on the IMP-6 spacecraft during the 1971 April 20-24 solar particle event. This was a fairly large and simple event following a flare on the 20th at 1945 hours, at 50° West solar longitude, and the data are of very high quality. Dr. von Rosenvinge has already done some analysis of this event. We felt that it would be a good event in which to learn how to read and process spacecraft data and test our preconceived ideas on what we would find.

The first thing we found was that it was not so easy to find the correct convective anisotropy to subtract from the observed total anisotropy as we had supposed. This subtraction has seemed to us to be necessary before anything else could be learned from anisotropy data. We therefore discovered a scheme for plotting the data is such a way that it was obvious that the non-convective part of the anisotropy was generally oriented along the local magnetic field. This scheme is described in the Appendix to this report. It is only a very coarse approach to anisotropy data, but we believe it may be a useful method for the initial analysis of future experiments. We intend to describe it soon in a brief publication.

The plotting scheme discussed above indicated also that in the first 12 hours or so of the event of 20-24 April 1971, the convective anisotropy in the lowest two energy ranges available to us was less than 10%, much too low to be protons. This was a disappointment, as we had hoped that the large fluxes and total anisotropies at this time would permit us to study the proton anisotropy on very short time scales. From the initial plot results, and from further evidence, we now believe these are electrons. Their anisotropy is in some ways even more interesting than the proton anisotropy, since having much lower momenta at the same energy, they have very small gyroradii and sample very small-scale magnetic turbulence. It will be enormously interesting to compare what we may learn from the diffusion of these flare electrons with the assumptions about the diffusion of galactic electrons of the same energy which are necessary to the present generation of modulation models.

Our next effort at the convective anisotropy involved the determination of the slope of the spectrum. We first tried to do it strictly by computer, got bizare results, and then plotted a few by hand. It was immediately clear that indeed we had a two - component spectrum for the first 12 hours or so of 21 April, and that the higher-energy component was protons. The lower-energy protons were delayed by travel-time, r/v which is 7 hours for 200kev protons. They came up to a power-law, $\gamma \sim 2$ down to ~ 100 kev by 1800 on 21 April. The lower-energy component decayed slowly after 0000 hours, and appeared to have a very steep spectral slope, $\gamma \sim 10$ or more. When these counting rates were re-plotted versus the detector electronic rather than incident proton thresholds a slope of $\gamma \sim 3.5$, quite typical for solar electrons, was found. We feel fairly certain then that these are electrons.

The technical anomaly we found concerns one of the incident proton thresholds in one detector. At late times in the event, when the spectrum had settled down, and all counts were protons, we kept getting a bump in differential intensity of one detector at a certain energy. No bump appeared in spectra from the other detector. The bump is removed by lowering the energy threshold assumed for one of the rates from 260 to 230 kev. We are investigating the instrumental basis, if any, for this effect.

Another technical difficulty arises from the spin-modulation of the unsectored rates due to inequities between the spacecraft spin period and the time counts are accumulated. We find half-hour integration times can yield a 20% difference between the sum of the sectored rates, and the unsectored rates. While it is in principle possible to remove this modulation, we find it a nuisance calculating the spectral exponents.

We have given up on finding second-order convective effects in this event (see reference 3, and section 2.1d of the proposal) since we realized the big anisotropies are largely electrons which have a small first-order convective anisotropy, and hence a minute second-order effect. It may yet be found in other events.

3. THEORETICAL RESULTS

The support of this grant for the first six months has permitted us to attend and give a paper (1. in the Bibliography) at the 13th International Conference on Cosmic Rays in Denver (in August 1973, so not technically in the time of this grant). In addition, we were able to complete and submit two theoretical papers on anisotropies for publication (2 and 3) and to begin work on a third which has been reported at one national meeting (6) and will be continued at another (7). Another paper (2) which was in preparation at the time of the proposal for this grant, but submitted before the grant became effective, has appeared in print. All of these papers deal with theoretical aspects of the diffusion and anisotropy of low energy cosmic rays.

CURRENT BIBLIOGRAPHY

1. "Particle Distribution Functions in Modulation Theory" (with L.A. Fisk and W.I. Axford) - 14th International Conference on Cosmic Rays, 1973, University of Denver, USA, 2, 663.

2. "Higher-Order Compton-Getting Anisotropies" (with A. Baloch and S. Webb, Imperial College, London) - Planetary and Space Sciences, 21, 1802.

3. "Cosmic-ray Anisotropies" (with L.J. Gleeson, University of California at San Diego) - submitted to Astrophysics and Space Science.

4. "Cosmic-ray Streaming Perpendicular to the Mean Magnetic Field" (with J.R. Jokipii and A.J. Owens, California Institute of Technology) - submitted to Astrophysical Journal.

5. Same as 3, summary presented at Tucson meeting of AAS/APS, December 1973.

6. "Upper Limits on $\kappa_{\perp}/\kappa_{\parallel}$ at Very Low Energies". presented at Tucson meeting of AAS/APS, December, 1973.

7. (Same title as 5; Further Developments in this Theory) to be presented at Washington, D.C. annual meeting of AGU, April, 1974.

APPENDIX: ANISOTROPY PLOTTING SCHEME

The plot is of the component of anisotropy from the sun versus the product of the component from the west and the cot angent of the angle between the magnetic field and the direction to the sun. If the anisotropy is the vector sum of a constant, radial, convective component, and a component of variable magnitude aligned with the magnetic field, the plot will be a straight line of slope ± 1 (sign depends on magnetic sector) and y - intercept equal to the convective anisotropy.

The reason this works is in the following equations. The radial component of anisotropy is

$$\delta_r = \delta_c + \delta_D \cos \varphi_B$$

δ_D is the amplitude of the diffusive anisotropy and where φ_B is the magnetic field angle. The east-west component has no convective part.

$$\delta_t = \delta_D \sin \varphi_B$$

Thus,

$$\delta_r = \delta_c + \delta_t \cot \varphi_B$$

The alignment of the data on a line of unit slope indicates the assumptions are valid. The intercept gives the convective anisotropy.